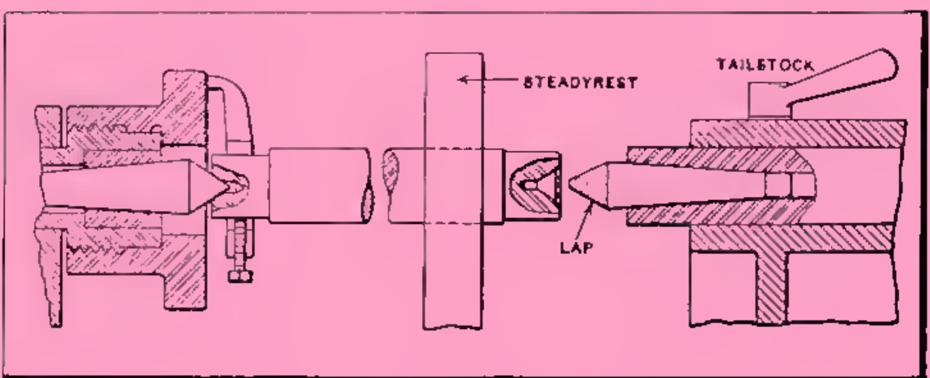
# LAPPING & POLISHING




E K HAMMOND

# LAPPING AND POLISHING

A TREATISE ON LAPPINO AND POLISHING PRACTICE, INCLUDING THE ABRASIVES USED FOR LAPPING, METHODS OF CHARGING LAPS, MATERIALS FOR POLISHING, AND POLISHING WHEELS

BY

EDWARD K. HAMMOND

CONTENTS

Modern Lapping Practice . . . . . . 1

Abrasives, Lubricants and Lapping Materials . 32

Polishing Methods . . . . . . . 41

**WARNING**

It should be remembered that the materials and practices described in this publication are from an earlier age when we were less safety conscious. Neither the methods nor materials have been tested to today's standard and are consequently not endorsed by the publishers. Safety is your responsibility and care must be exercised at all times.

# LAPPING AND POLISHING

## CHAPTER I

### MODERN LAPPING PRACTICE

THE unusual demand for different types of precision gages for handling war work led to the development of numerous improved methods of lapping. It is the purpose of this treatise to present a comprehensive review of the most improved practice in lapping operations. Laps may be used for increasing the inside diameter of holes or for reducing the outside diameter of cylindrical pieces to the specified size; tools of this type may also be employed on flat surfaces and on pieces of certain other shapes.

The term "lap" is used to denote a tool made of a fine grade of gray cast iron, brass, or some other fairly soft metal, which may be charged with an abrasive to grind the work down to size. Laps made of box wood or hard maple are extensively employed on certain classes of work, especially for imparting a final finish after the work has been brought to size. Various abrasive materials are used for charging laps, among which the aluminous oxide abrasives, alundum, made by the Norton Co., Worcester, Mass., and aloxite, made by the Carborundum Co. of Niagara Falls, N. Y., find the most general application for lapping when rapid cutting is required. Laps charged with diamond dust are also used for this purpose, while emery is the most generally used abrasive for charging laps that are used for imparting a final finish where a high polish is desired.

**Form of Lap.** The form of the lap varies according to the work on which it is to be used. For instance, a lap for increasing the inside diameter of a hole will be of cylindrical form, while a lap for reducing the outside diameter

of a cylindrical piece to the required size will have a hole in which the work is inserted. In either case, about 0.002 inch must be allowed on the diameter of the lap to form a clearance space for the abrasive material, which projects out from the surface of the lap.

**Procedure in Lapping.** In order to understand the way in which a lapping operation is performed, it should be borne in mind that the lap is made of soft metal, while the piece to be lapped is usually made of hardened steel. The abrasive will always embed itself in the softer metal, so that the harder the material to be lapped the harder the metal from which the lap may be made. On the other hand, the harder material will often be charged to a certain extent, unless the lap is very soft. For this reason lead and wood are frequently used in making finishing laps, as they tend to "uncharge" the lapped surface and produce a high polish on the work. On the more accurate grades of work, the harder laps are used only for rough-lapping.

The lapping abrasive is mixed with oil, equal parts of kerosene and lard oil being one mixture that gives satisfactory results. The abrasive and oil are mixed together and then applied to the surface of the lap; and the abrasive gradually becomes embedded in the lap until its entire working surface is completely charged. Either the work or the lap (according to conditions) must be rotated at a number of revolutions per minute which will give a surface speed of approximately 5000 feet per minute. At lower speeds, it is found that an abrasive material will not give satisfactory service in cutting hardened steel. Experience enables the operator to develop a very fine sense of touch. This faculty is an absolute necessity, because the lapping operation is depended upon to remove a very small fraction of a thousandth of an inch from the diameter of the work; hence the operator must learn to determine where the slightly high spots are located, and continue the lapping at such points until a uniform result is secured.

**Lapping "Mini-plug" Gages.** The name "mini-plug" has been applied to plug gages made by the Fortney Mfg. Co., Belleville, N. J., owing to the extremely small sizes in which

these tools are made. The range runs from 0.007 inch up to 1.000 inch in diameter, and the gages are guaranteed to be accurate within 0.00005 inch. To produce tools of this type within such close limits of accuracy, means that the greatest care must be taken in lapping the work during the process of manufacture. The gages are first reduced to

Fig. 1. Reducing the Outside Diameter of a "Mini-plug" Gage in a Lapping Machine

within from 0.0005 inch to 0.00075 inch over size, according to the diameter of the work. A pair of aloxite olistones is used for this purpose, between which the work is rubbed while being rotated by power; with relatively new stones, powdered aloxite and oil will aid their cutting action.

When the micrometer indicates that the work has been brought down close enough to the required size, the lapping

operation is started. The gage is chucked in a horizontal spindle machine of the form shown in Fig. 1, and a lap charged with No. 65A aloxite is moved back and forth along the length of the surface to be finished. The machines used for these lapping operations are of quite simple construction. They are made of electric motors for sewing machines, built by the Hamilton-Beach Mfg. Co., of Racine, Wis., which have a foot-pedal control for the switch. In equipping these machines for lapping, the driving pulley was removed and a drill chuck mounted on the armature

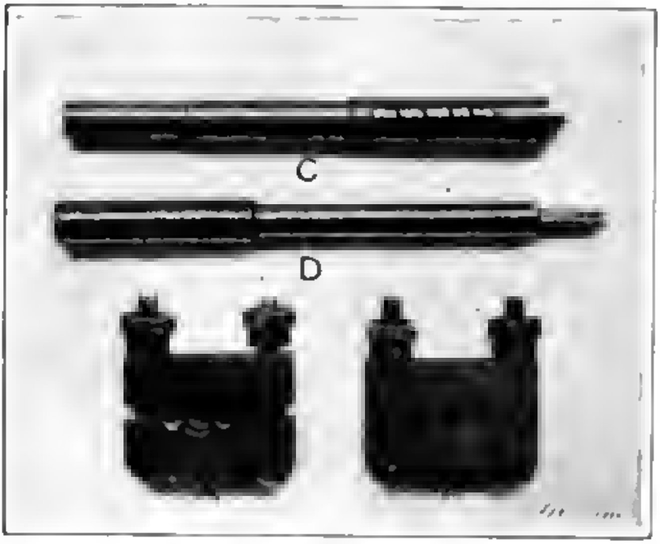



Fig. 2. (A) and (B) Outside-diameter Laps. (C) and (D) Inside-diameter Laps

spindle in its place, so that either the cylindrical work or the lap may be held in this chuck, according to whether the inside diameter of the hole or the outside diameter of the work is to be lapped. The operator is able to start or stop rotation of the spindle by means of the pedal control, and the speed of rotation may be regulated within sufficiently close limits by retarding the revolution of the drill chuck with the thumb and index finger.

**Making the Laps.** For lapping the outside diameter of plug gages and other cylindrical-shaped work, a split lap

is used, which is of the form shown at $A$ and $B$ in Fig. 2. It will be seen that each of these laps has four different openings for lapping work of various diameters. The method of procedure in forming the openings will vary according to the diameter. For holes of considerable size, the easiest method is to clamp the two halves of the lap together, and next drill and ream the hole to slightly less than the required diameter. Then when the hardened piece of work is put between the two halves of this lap, the abrasive will start to "bite back," because the lap is softer

Fig. 3. Checking the Accuracy of Lapped Gages by Means of Prestwich Fluid Gage

than the work. In this way, the size of the opening will be increased; but very soon a quantity of the abrasive will become embedded all the way around the opening in the lap, and from that time on, the action will be reversed so that the abrasive material will grind down the hardened work until the required size has been reached.

The lapping operation is continued until the diameter of the work has been reduced to the specified size, as indictated with a Prestwich fluid gage, Fig. 3, which is used in conjunction with a master plug, the size of which has

been verified on a Pratt & Whitney precision measuring machine. For making very small sizes of split laps, it is not feasible to drill and ream the opening. In making such tools, the method of procedure is to use a very thin saw to cut a small impression in the face of each half of the lap; after this has been done, the work is chucked and the lap applied to it in the usual way. Owing to the back-biting action of the abrasive, the opening in the lap will soon be rounded out to the required shape and size.

From the illustrations of split laps shown at *A* and *B* in Fig. 2, it will be seen that the two halves of the lap are held together by screws, with a nut and washer on each screw for drawing the two halves of the tool inward against the work. At the time the lap is first applied to the work, the diameter of the piece that is being lapped is considerably over size and the two halves of the lap fail to come together; but as the operation approaches completion, the diameter of the work is reduced, and the nuts are accordingly tightened in order that the abrasive may be applied to the work with the necessary amount of pressure. This tightening of the screws is continued until the size of the work has been reduced as much as required. Despite the protection which the abrasive affords against the wearing of the lap, there is a tendency for the size of the opening to increase. This is offset by occasionally removing metal from the faces of the two halves of the lap which come together at the split. After compensation has been made in this way, the lap has to adjust itself again to the work. until the opening has been brought to the proper size. It is of interest to note that when a new lap is first used, it does not cut very freely, because the abrasive has not become embedded in the lap. While the abrasive is being carried around by the work, it has more of a cutting influence on the lap than on the piece which is being reduced to size. It is only after the abrasive has been embedded, so that it remains stationary while the work revolves, that an efficient cutting action can be expected.

**Laps for Operating in Holes.** At *C* and *D* in Fig. 2, there are shown two types of laps for use in sizing the inside diameter of a ring gage, or any similar piece of work. The

principle of operation of both these laps is the same, although the result is obtained by different methods. The lap shown at *C* is split from the end, so that a small wedge may be driven into the split for expanding the lap as the size of the opening in the work is increased. This lap is made with a spiral groove running around it, of a somewhat similar form to the oil groove in a bearing; and the function of this groove is also the same as that of a bearing oil groove, namely, to assist in distributing the emulsion of oil and abrasive over the surface of the work that is to be lapped. In making a lap of this type, care must be taken to prevent a tendency for the tool to produce a bell-mouthed opening in the work. This is done by turning the body of the lap to a taper of abont 0.001 inch, with the small diameter at the open end of the split. With a lap made in this manner, driving in the tapered wedge results in expanding the lap in a way that brings it to approximately a true cylindrical form. But regardless of the amount of care that is taken in making the lap, dependence must still be placed upon the skill and experience of the man who uses the lap to bring the opening in the work accurately to size and to have it of a uniform diameter from end to end.

A certain amount of bell-mouthing is practically inevitable, because the loose abrasive tends to crowd in as the lap passes through the end of the hole; but a slight rounding of the edge is seldom objectionable, as it removes the sharp corner at the end of the hole. However, it is common practice to leave a small lip or hub at the end of a ring gage or similar piece, which is removed after the lapping has been completed, in order to remove the bell-mouthed end of the hole.

The lap shown at *D* is designed on the same principle as the one which has just been described, but the method of obtaining the result is somewhat different. It will be seen that two transverse holes have been drilled through the body of this lap. A fine scroll saw is then used to cut a slot connecting these two holes. Through the end of the lap body, there is an axial hole which has been reamed

to a slight taper, and by pushing a tapered pin into this hole, the lap can be expanded as the size of the opening in the work is increased. With a lap of this design expansion results in making the diameter slightly larger at the center, with the size decreasing toward the two ends of the body. The departure from a truly cylindrical form is slight, and the skill of the operator enables him to produce perfectly accurate work with such a tool. Both of the laps shown

Fig. 4. Machine for lapping Thread Gages, etc.

at *C* and *D* are made of brass. This material was selected because it is soft enough to become readily charged with the abrasive, and yet it is not so brittle as cast iron. If an attempt were made to produce a lap of this shape from cast iron, the torsional and bending stresses would be likely to cause the lap to break before it had given a reasonable amount of service.

**Lapping Thread Gages.** After they have been machined as close as possible to the required dimensions, both male

and female thread gages have to be lapped to obtain the high degree of precision required in tools of this type. The lap for working in a female thread gage consists of a threaded plug charged with suitable abrasive, which is given a reciprocating rotary movement inside the work; similarly, the lap for reducing a male thread gage to size consists of a threaded ring which is screwed back and forth over the gage. There are various methods of applying the required oscillatory rotary movement for handling both of these classes of lapping; but one of the most convenient and efficient means provided for the purpose is a small lapping machine of the type shown in Fig. 4, which is built by the H. E. Harris Engineering Co., of Bridgeport, Conn. It consists of two pulleys loosely mounted on the spindle, which are driven in opposite directions by an open and a crossed belt. Between these pulleys there is a friction disk keyed to the shaft, and by means of the lever at the left-hand side of the machine, the operator is able to engage the spindle with either the forward or reverse drive.

A machine of this type can be used for lapping either male or female gages. In the former case, a drill chuck is mounted on the lapping machine spindle and the thread gage is carried by this chuck. The operator holds the clutch lever in his left hand and the lap in his right hand; then it is an easy matter, by constantly reversing the direction of rotation of the spindle, to screw the lap back and forth over the threaded portion of the gage. Exactly the same procedure is followed in lapping female gages, except that in this case the lap is mounted in the drill chuck and the gage is held in the operator's hand. The method of operation is identical in both cases. After he has attained the necessary experience and dexterity in using a machine of this kind, the operator will be able to concentrate the action of the lap on that portion of the gage which must be reduced in size, without lapping down adjacent threads which have already been brought to the required dimensions. The machine is mounted on the work-bench at about 8 inches from the forward edge, so that an arm rest is provided on which the workman can support his elbows. In work such as thread gage lapping, it is important to elimi-

nate the fatigue factor as far as possible, because the results obtained are largely dependent upon the workman's sense of touch, and this will become dulled during the late hours of the day, if he becomes unduly fatigued.

**Design of Thread Gage Laps.** There is considerable diversity of practice both in making the laps and in selecting the types of abrasives with which they are charged. A brief consideration of this point might lead one to the conclusion that it is strange for two men engaged in lapping thread gages of precisely the same design, and made of the same kind of steel, to be able to obtain equally satisfactory results with laps made of different materials and charged with quite different abrasives; but more mature consideration will make the reason apparent. In an operation like lapping, the personal equation plays an important role, and as one man's sense of touch and method of procedure in doing his work is likely to differ considerably from that of the man working next to him, it is entirely conceivable that differences of practice, both in selecting materials for making the laps and in the choice of abrasives for charging them, may be the means of offsetting such differences of temperament among men employed in the lapping department. During the war, when the H. E. Harris Engineering Co. was engaged in the manufacture of thread gages, it was found good practice to provide each experienced operator with the kind of laps and abrasive materials for which he expressed a preference. This was particularly true in the case of men who had acquired their early training in other plants.

**Materials for Thread Gage Laps.** Various materials may be successfully employed for making thread gage laps, some of those which are most commonly used being machine steel, gray cast iron, copper, and brass. As previously stated, laps for operation in female thread gages are plain threaded plugs. Owing to the desirability of providing means of adjustment, laps which are to be used on male thread gages are of slightly different design. Reference to Fig. 5, in which are shown a number of these tools, will make it apparent that the lap consists of a threaded ring which is split clear through in one place and partially split

in two other positions at 120 degrees from the first one. This lap is placed inside of a holder which is similarly split and provided with clamping screws that can be tightened to

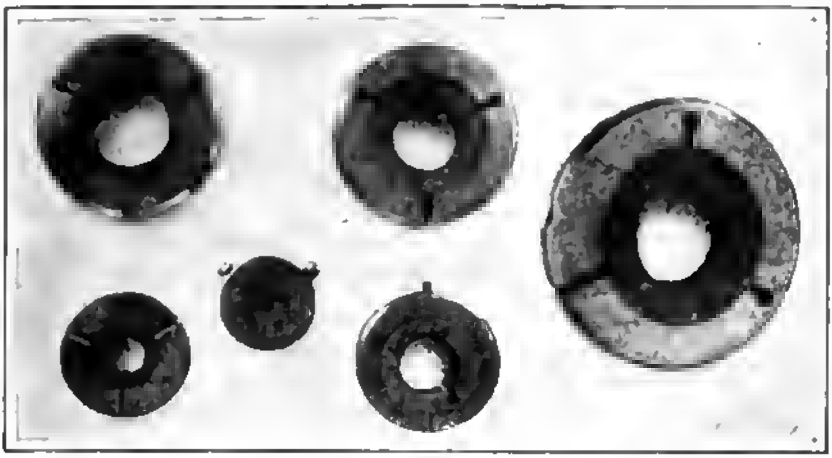


Fig. 5. Thread Gage Laps, showing Split Construction of Lap and Holder to afford Adjustment

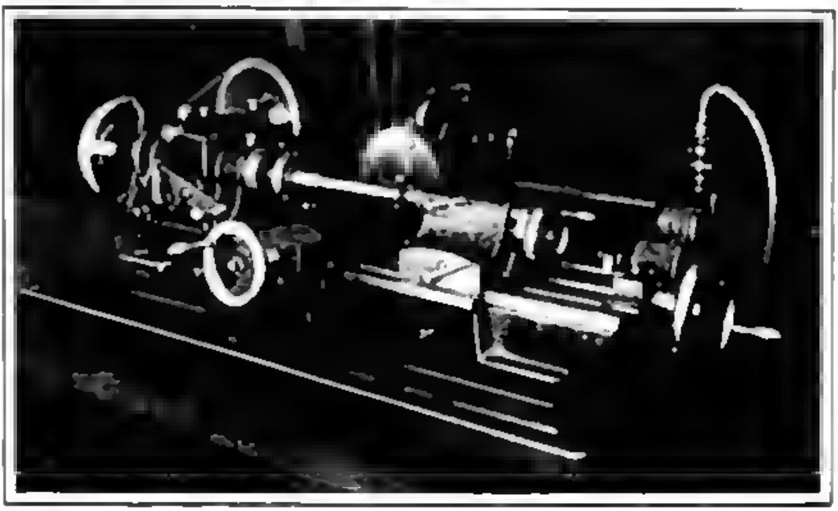


Fig. 6. Precision Lathe equipped with Thread-milling Attachment for lapping with a Rotary Lap

compress the holder on the outside of the lap, thus causing it to contract sufficiently to compensate for wear. In the case of small sized laps, instead of having the holder split, a

practice is made of placing radial screws in the holder, which can be tightened up on the lap ring to produce the same compressive effect that is produced by a different arrangement of clamping screws used on larger sized holders. Adjustment provided in the lap affords a means of regulating its size so that an experienced mechanic is able to tell by the "feel" whether the tool is cutting properly. No attempt is made to obtain any definite relationship between the size of the lap and the finished size of the work, as wear of the tool and breaking down of the abrasive on its surface would make such a condition of only temporary duration. All sizes of holders are knurled on the outside in order to provide a firm grip for the operator.

**Abrasives for Charging Laps.** For average conditions of operation it will probably be found that a machine steel lap will give the most favorable results, and it can be charged with either fine diamond dust, carborundum, flour of emery, flour of rouge, or flour of crocus. In any case it is important for the abrasive to be reduced to an impalpable powder which is mixed with oil before using. Some men of wide experience in lapping do not depend upon the fineness of commercial abrasives without subjecting them to a special refining treatment. One good way of preparing the abrasive is to mix it with kerosene oil until the emulsion so produced has about the consistency of milk. After shaking, any coarse particles will settle to the bottom more rapidly than the finer ones; and by allowing the emulsion to stand for a sufficient length of time for the abrasive to settle to the bottom, the fluid can be decanted off. Care is taken to use only a portion of the abrasive taken from the upper layer. In line with the policy of allowing operators to express their preferences for a given type of lap, the engineering company previously referred to found that it was also desirable to have each man prepare his own abrasive in order that he might make it of exactly the degree of coarseness with which he had grown familiar.

**Rotary Laps for Small Work.** Lapping is a modification of the process of grinding, and in order to obtain efficient

results, it is necessary for the abrasive material to be passed over the surface of the work at a suitable cutting speed. On small sizes of thread gages, it may be found that the surface to be lapped is so close to the center of the rotation that difficulty is experienced in obtaining the necessary surface speed for the lap to provide an efficient cutting action. To overcome this difficulty, the H. E. Harris Engineering Co. adopted the use of rotary laps so that the work and the lap could be revolved in opposite directions, thus greatly increasing the so-called "surface" speed between the abrasive and the work. The lap used for this purpose is a steel disk with its edge formed to fit into the thread of the gage to be lapped. To use a tool of this type, it is necessary to impart a longitudinal feed movement to the lap, as well as to rotate both the lap and the work, so that the lap may follow the thread which it is desired to reduce to size. As in other cases of thread gage lapping, a reciprocating movement is employed so that the lap passes continuously back and forth over the threaded surface of the work during the operation.

A precision lathe equipped with a thread milling attachment is utilized for this purpose, the machine being shown in Fig. 6 set up for a lapping operation. The equipment used on the machine is similar to that employed for thread milling, except that the lapping spindle is provided with a pulley carrying a belt running up to a large driving pulley on the overhead works, to impart the necessary speed of rotation, which is much higher than that utilized in thread milling. Special means must be provided for charging a lap of this kind. The tool used for this purpose is shown in Fig. 7. It consists of an arm which carries two bevel-faced wheels so formed and mounted that the two faces of the wheels bear against the lapping surfaces of the steel disk. The abrasive generally used on a lap of this kind consists of diamond dust prepared according to instructions that will be given further on in this chapter.

**Lapping with Diamond Dust.** In some shops lapping with diamond dust has fallen into disrepute, because the greater cost of the abrasive did not seem to be justified by

the results obtained, either in the speed of cutting or in the perfection of finish. This has been due primarily to the fact that an attempt was made to force the lap to cut too fast. In order to obtain the best results with diamond laps, very light cuts and high speeds should be used. Diamond dust is not supposed to be broken down in cutting, as is the case with other abrasives; it does not break down readily, and the result of crowding the work is to dull the cutting edges of diamond chips. An example similar to this difference between diamond dust and other abrasives is seen in grinding wheel-truing devices. A diamond wheel-truing tool depends upon its sharp cutting

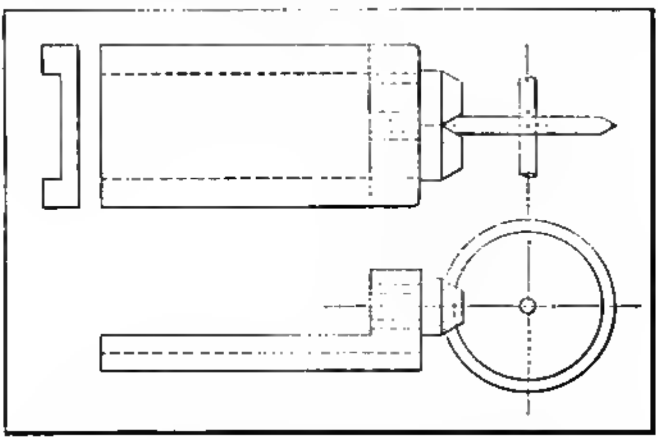


Fig. 7. Fixture for charging Rotary Laps of the Type used on the Machine shown in Fig. 6

edge, while an abrasive truing wheel is supposed to break down while truing and thus present new sharp edges to the grinding wheel that is being dressed.

**Pratt & Whitney Co.'s Practice in Lapping Thread Gages.** At the Pratt & Whitney Co.'s plant in Hartford, Conn., the methods used for lapping thread gages are similar to those which have already been described so that further details are unnecessary. It will be of interest to note, however that this company has found that the best results are obtained with laps made of cold-rolled steel or machine steel, the former material being preferable, because it is softer and easier to charge with abrasive. The tool-rooms

of this plant have tried to use laps made of cast iron, but for thread gages little success has been obtained because of the difficulty experienced in obtaining full threads that will stand up without a tendency to flake off and wear with undue rapidity at the tops of the threads. In this plant it is a practice to perform the thread gage lapping operations at two steps, a roughing cut being taken with a lap charged with a No. 2 F or 3 F carborundum mixed with a sufficient quantity of kerosene to form a fluid of about the consistency of cream. After this preliminary lapping operation, a finishing cut is taken, using a lap charged with No. 4 F Turkish flour of emery, or No. 65 F alundum, either of these abrasive materials being mixed with sperm oil or lard oil.

**Testing Accuracy of Lapped Thread Gage.** It is not within the province of this book to enter into a discussion of methods of measuring internal and external threaded work. Such methods have recently received considerable attention in the technical press. However, in passing, it may be mentioned that any recognized method of measuring is utilized, such as the three-wire system supplemented by a Prestwich fluid gage, to test the dimensions of the gage as the lapping operation proceeds, not only with a view to ascertaining when the work has been reduced to the required size, but also to find variations at different positions on the work, in order that the lapping action may be concentrated at the high points to provide for reducing the gage uniformly to the required dimensions.

**Lapping Snap Gages.** For lapping the measuring surfaces of snap gages, the Pratt & Whitney Co. makes use of an adjustable form of lap which not only has sufficient compensation so that the same lap can be utilized for finishing the surfaces on gages of a number of different sizes, but the compensation that is afforded also enables the lap to be adjusted to take up the very slight amount of wear that develops as a result of constant use. Fig. 8 shows that these laps consist of two wedge-shaped members, with the inclined faces of the wedges opposed to each other. The lapping surfaces are on the outside and adjustment is

obtained by sliding the two members of the lap relative to each other, so that the thickness may be increased or diminished to give the required distance between the lapping surfaces of the tool and the lapped faces on the work. After the lap has been set, it is secured in place through the use of C-clamps.

In cases where a greater degree of adjustment is required than that which is furnished by the inclined faces of the lap, such a result is accomplished by the use of shims or a

Fig. 8. Adjustable Parallel Lap used for lapping Snap Gages

filler block of the proper thickness, which is introduced between the inclined faces of the two halves of the lap. Great care must be taken to have the shims or filler block of a high degree of parallelism, in order to avoid interfering with the accuracy of the tool. In handling this work, it is the practice to take a roughing and a finishing cut, the preliminary operation being performed with laps charged with 2 F carborundum, while the finishing operation is performed with laps charged with 4 F Turkish flour of emery. These wedge-shaped laps are made of cast iron, which experience

has shown to be the best material for making laps for use on flat surfaces of considerable size.

The reason for dividing the operation into two steps is to avoid errors resulting from the tendency of the work to expand slightly while the roughing cut is being taken. By allowing sufficient time for the work to return to a normal temperature and size before taking the finishing cut, there is little chance of introducing an error, because the rise of temperature and expansion of the work while taking the light finishing cut are practically negligible factors. This practice of removing the bulk of the metal by a preliminary operation, and then taking a very fine cut while lapping the work to its final size, should be followed in all

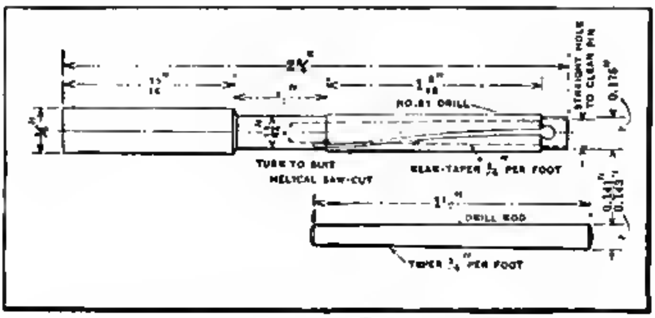



Fig. 9. Internal Lap which is especially suited for lapping Small and proportionately Long Holes

cases of internal lapping where the maximum degree of accuracy is required.

**Internal Lap.** An internal lap that is especially suitable for use in lapping small holes which are long in proportion to their diameter, is shown in Fig. 9 which gives sufficient information for making a lap of this type. Copper is considered the most suitable material to use in making these laps. It will be noted that the lap is necked between the handle and the body and that the end is turned down in a similar manner.

Two holes are drilled through these necks, as shown, being connected by a helical saw-cut—a feature which prevents the hole from being lapped out of round and also provides for removing unevenness caused by hardening. The end of the lap is drilled out to a depth equal to the length of the turned

portion, so as to clear the large end of the tapered pin when the lap is expanded. The diameter of the tapered pin in relation to that of the body of the lap should be such as not to leave the metal surrounding the pin so heavy that it will not conform to the taper of the pin when the lap is expanded.

This lap has been used for lapping holes 0.185 inch in diameter, and 1¼ inches long. Sufficient accuracy has been obtained to make it impossible to enter a 0.185-inch diameter plug either dry or by using ordinary oil, but with oil which

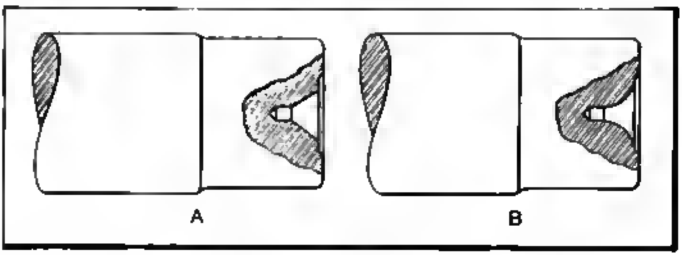



Fig. 10. Two Types of Centers for Arbors

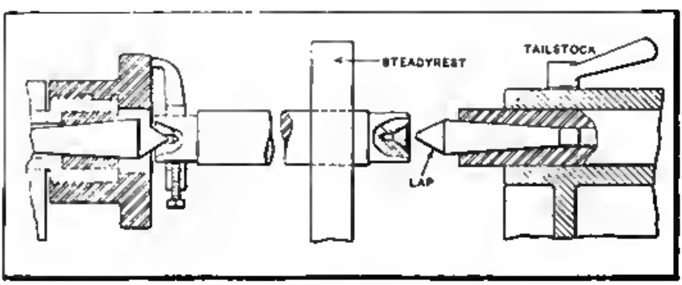



Fig. 11. Method of lapping Arbor Centers in a Speed Lathe

had been used it was found possible to get the plug into the hole. As an experiment, a plug was made 0.0001 inch over size and this plug could not be pushed through, no matter what kind of oil was used. In lapping the hole, no extraordinary care was taken, a fact which clearly demonstrates the satisfactory results which can be obtained with a lap of this design. Previous to making this lap, a slit bushing was tried on a tapered arbor but without success, because it was found that the lap expanded much faster on the large end of the arbor than on the small end. Under

these conditions, it was impossible to obtain a straight hole or to prevent bell-mouthing.

**Lapping Arbor Centers.** There are two types of centers used in arbors. One is the straight vee or 60-degree angle and the other, the rounded form which gives a line bearing. Of these, the rounded form shown at *B* in Fig. 10 is preferred by some small tool manufacturers. The reason that this type of center meets with favor is that an arbor provided with such centers can be used for either taper or straight turning with satisfactory results; furthermore, it will retain its accuracy for a greater length of time, as only a line contact is secured and it is not so easy for dirt to accumulate as in the straight 60-degree center.

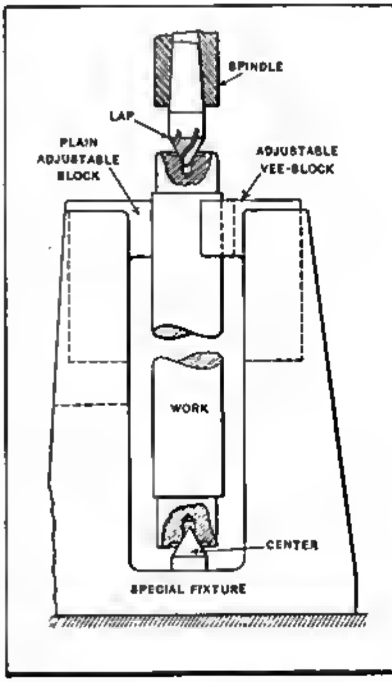



Fig. 12. Method of lapping Arbor Centers in a Drilling Machine

There are various methods of lapping centers, the one used being governed to a certain extent by the type of center provided in the arbor. A few methods of lapping are shown in Figs. 11 and 12. The first method, shown in Fig. 11, illustrates how the lapping can be done in an ordinary speed lathe. The arbor to be lapped is held on the center, driven by a dog from the faceplate, and is supported on the outer end by means of a steadyrest. The lap is then held in the tailstock of the lathe and is moved back and forth by hand, so as to prevent it from cutting grooves in the center. The lap should be made either from box wood loaded with emery dust, or from copper charged with diamond dust. Unless the center has been carefully formed before hardening, and the hard-

ening has been done in such a way as to prevent the center from distorting to any extent, this method of lapping is not entirely satisfactory.

Another method of lapping is illustrated in Fig. 12. Here the work is done in a sensitive drilling machine by holding the arbor in a special fixture in an upright position, and the lap in the chuck on the spindle. The spindle is then given an up and down movement to prevent cutting grooves in

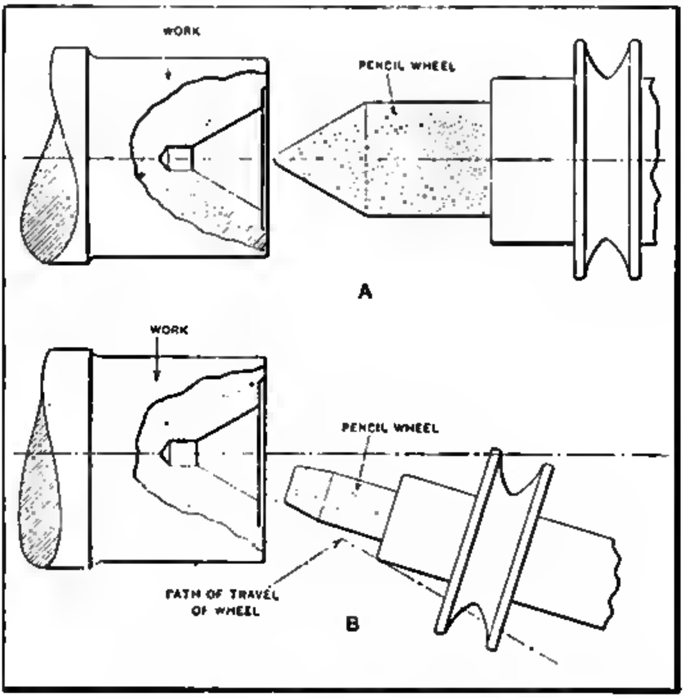



Fig. 13. (A) Form-grinding an Arbor Center; (B) Grinding an Arbor Center by the Generating Process

the center; it is advisable to cut grooves in the lap extending toward the point to assist the lapping compound in spreading along the surface of the lap. Cutting helical grooves in the lap also increases rapidity in accomplishing the work.

A still better method of lapping is to use a single-spindle valve grinder in which a much more satisfactory oscillating movement of the lap can be obtained. A drilling machine however, could be fitted up with a device for accomplishing

the same purpose. By securing an oscillating movement of the lap it will be found that the work is accomplished much more rapidly than when the lap is withdrawn and inserted in the center without any oscillating movement, and in addition there is less danger of scoring the center.

The lapping of a center under the most favorable conditions is a tedious operation, and a highly satisfactory job cannot be obtained if the center is at all rough or distorted during the heat-treating operation. It will be found to be much more satisfactory to grind the centers. Considering first that the center is of the 60-degree type with a straight surface, there are two methods of grinding. That shown at *A* in Fig 13 is to use a pencil wheel similar to that used for grinding gear-cutting hobs, and taper it down on the end to an angle of 60 degrees. This wheel should be rotated at a speed of not less than 10,000 revolutions per minute. In fact, the higher the speed the better the results. For this work, therefore, a No. 2 universal cutter and tool grinding machine provided with an internal grinding attachment could be fitted up. One end of the arbor could be supported and held on the driving center and the other end supported by a steadyrest, the pencil wheel being held in the place of the regular internal grinding wheel by making a special spindle for holding it. A pencil wheel of about 80 to 120 grain, grade O or P, should be used. Of course, the grade and grain of wheel will be governed largely by the condition of the center. If the center has been nicely finishd before hardening, a very fine, hard wheel could be used and good results obtained, whereas if the center is rough and considerable material is to be removed in grinding, such a wheel would not give as satisfactory results.

Still another method of grinding an angular center would be to generate the center bearing as shown at *B* in Fig. 13. This also could be done on the same type of machine by simply setting the wheel slide at the required angle. This method of grinding will give much better results than that first mentioned. The center will be generated and can be made exactly to a 60-degree angle; in addition, a smoother surface will be obtained.

The straight center does not give as satisfactory results

as one which is rounded off, and for grinding this center the pencil wheel could be formed by a radius diamond truing device and then brought in on the work the same as in grinding a 60-degree center.

The length of time required for lapping or grinding a center depends to a considerable extent on the method used and the finish required. Lapping a center in a speed lathe is a slow and tedious operation; lapping in a drilling machine with an up and down movement is a little faster; whereas lapping in a valve grinder is faster still. To lap a center correctly would require anywhere from fifteen minutes to a half hour, depending on the method used; whereas in grinding a center by the methods previously described the time could easily be cut to half or probably less. To grind two centers in an arbor by the generating process would require approximately ten minutes. To grind a rounded center with a form wheel would probably take about the same time, and if a satisfactory wheel were used it would not be necessary to true the wheel up after grinding each center. This method of forming wheels to definite shapes for grinding is being used more and more, and the grinding of tooth shapes of gears and hobs is a good example of the possibilities of form-wheel grinding.

Improvements are constantly being made, however, in the binders and methods of manufacture of grinding wheels, which tend to make possible the use of formed wheels for grinding shapes that heretofore could not be accurately finished after hardening with dispatch.

**Surface Plate Laps.** For lapping down surfaces of considerable area, use is made of what is known as a "surface plate" type of lap. It consists essentially of the cast-iron surface plate with a charge of abrasive material that affords the required cutting action on a piece of work rubbed over the surface of such a tool. A description of the use of a large lap of this kind would be incomplete without emphasizing the fact that it is of the utmost importance to employ an irregular movement in rubbing the work over the surface of the tool. The reason for so doing is not difficult to understand. It will be evident that if a mechanic formed a practice of rubbing a piece of work straight back and forth

across the middle of the plate, a depression would soon be worn at one point, which would greatly impair the accuracy of the work.

Probably two of the widest extremes in the range of work on which a lapping operation may be required, are seen in the case of large pieces that are rubbed down on a surface plate and in the case of pieces of work with small grooves, etc., in which it may be necessary to lap down small sized surfaces to a high degree of accuracy. For these local lap-

Fig. 14. Use of Local-action Lap for finishing the Vertical Walls of a T-slot

ping operations, use is made of what is known as a "pencil" type of lap, which is made of a bar of copper about the size of an ordinary lead pencil, one end of the bar being flattened and bent over so that it lies in a horizontal position as shown in Fig. 14, when the lap is inclined in about the same way as a lead pencil would be while writing. There is little difference in practice in charging laps, regardless of their shape or size, but it is the general rule to take two cuts, the first of which is done with a lap charged with a No. 2 F-

carborundum, while the finishing cut is accomplished by using a lap charged with No. 4 F Turkish flour of emery.

It is the practice to mix the abrasive with either lard oil or sperm oil, and the men employed to perform lapping operations have small dishes of the oil and abrasives on their work-benches, into which they can dip with a small steel spatula and bring out a sufficient quantity of oil and abrasive to apply to the rotating lap. Experience has shown that it is also beneficial to apply a few drops of kerosene or gasoline to the lap occasionally, to afford a result somewhat similar to that of a cutting lubricant on a piece of work handled by a machine tool, the theory being that the kerosene or gasoline tends to wash away the very fine chips of metal that are abraded from the surface of the work by the lap.

The Norton Co. of Worcester, Mass., has had many years of experience in recommending abrasive materials for use in charging laps, and advises 2 F and 3 F alundum flour for charging thread gage laps and for other classes of gage lapping. In some cases it will be found desirable to use a 4 F grain, and for the very finest gage lapping operations the use of 65 F alundum is advised.

**Lapping Die Openings with Diamond Laps.** Die-castings are used in automatic counters made by the Veeder Mfg. Co., of Hartford, Conn., and this firm not only produces the castings that are needed to supply its own requirements, but also manufactures this product for sale to other manufacturers. Men who have had experience in the die-casting industry know that the dies used for this work must be extremely accurate, and in the Veeder tool-room a practice is made of lapping certain openings in the dies with laps charged with diamond dust. By this means, it is possible to hold the dimensions of such openings within 0.00005 inch or less. In this chapter information has already been given in regard to the performance of various internal and external lapping operations using carborundum, alundum, flour of emery, rouge or crocus as the cutting medium that is applied to the lap. These abrasives are highly satisfactory where lapping is depended upon to remove only about 0.0005 inch of metal to reduce the work to the finished size;

but in the Veeder tool-room, although the work done by laps charged with diamond dust is a true lapping operation, the term "grinding" is quite generally applied to it, because the diamond lap is used to remove an appreciable amount of stock after the grinding wheel has finished its work. This is possible because the diamond lap cuts far more rapidly and freely than a lap charged with any of the other abrasives that have been mentioned. For laps charged with some cutting medium other than diamond dust, it is usually the practice to leave from 0.0002 to 0.0005 inch to be removed by the lap, while in the case of diamond laps, owing to the rapidity with which they operate, satisfactory results

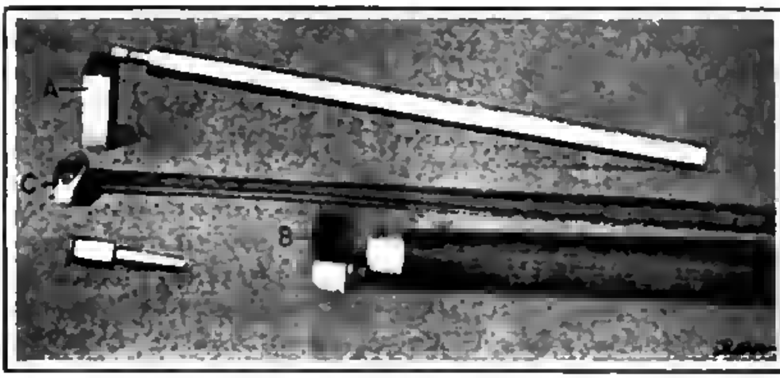



Fig. 15. Tools used for charging Laps with Diamond Dust

can be obtained by leaving as much as 0.002 to 0.006 inch of metal for lapping.

**Method of Making Diamond Laps.** Various metals may be used for making laps that are to be charged with diamond dust, but at the plant mentioned the standard materials are either machine steel or copper, steel being employed in the majority of cases. In making a lap, there is nothing unusual about the machine work, which consists simply of turning up a blank of the required shape and size. This blank must then be charged with diamond dust, after which it will be known as a "lap," and the procedure in handling the charging will naturally vary in the case of laps made of copper or steel. Copper being a softer metal receives the diamond dust more easily, hence it is merely necessary to deposit on

the face of a hardened steel block, shown at *A* in Fig. 15, a small amount of the dust moistened with oil to prevent it from flying, and after placing the cylindrical surface of the lap on this diamond dust, to roll it between the block *A* and the hardened steel face *B* of a tool provided for that purpose. From the illustration it will be apparent that the rolling tool is furnished with a handle of such a size and shape that the workman may grasp it in his hand and apply sufficient pressure to force the lap down on the diamond dust; this causes it to become embedded in the surface of the lap, as the copper is softer than either the face of the block or the rolling tool.

**Charging Steel Laps.** In charging steel laps, more trouble is likely to be experienced, owing to the greater hardness of the metal in which the diamond dust must be embedded. The charging of a steel lap is accomplished by first placing diamond dust on the face of block *A*, as previously explained, and then putting the lap on top of the diamond dust and tapping it with a small hammer *C*, the lap being turned slightly between successive blows of the hammer so that its entire face is exposed to the dust. After the work of charging has been started in this manner, the rolling tool *B* is used in the manner that has already been described, in order to provide for forcing in the particles of diamond which have already been partially embedded in the lap. A toolmaker who has not had experience in making diamond laps may ask the question: "How is one to ascertain when a lap has been thoroughly charged?" and this question would be answered by the single word "experience." However, it is noteworthy that there is very little danger of overcharging a lap, as the action of embedding the diamond dust is more or less self-compensating, that is to say, it is a very simple matter to start getting the dust to penetrate the face of the lap, but after the entire surface has been charged with abrasive, it has become so hard that the penetration of additional diamond dust is greatly retarded.

**Preparing Diamond Dust for Use in Laps.** Fig. 16 shows the type of pestle and mortar that is used for crushing diamonds to the degree of fineness that is required of the dust that is used for charging laps. Either white or black

bortz diamonds are used for the purpose, and as this material is quite expensive, care must be taken to avoid all unnecessary losses. Two of the means used for this purpose consist of placing a few drops of olive oil in the mortar to retard the tendency of the diamond chips to fly out from under the pestle, and using a rubber washer surrounding the pestle and coming down over the top of the mortar in order to make it as difficult as possible for any chips of diamond to fly out. During the process of crushing diamonds in a mortar, pieces of various sizes will be produced, and after the diamond dust has been reduced to what appears to be the required degree of fineness, it is necessary

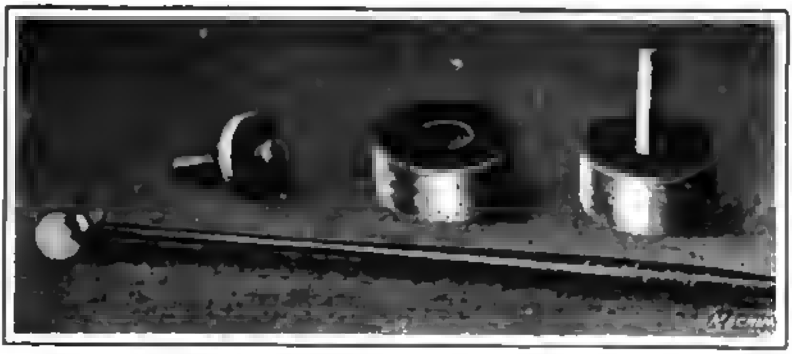


Fig. 16. Pestle, Mortar, and Hammer used in crushing Diamond Dust for Use in charging Laps

to grade it into portions containing particles of uniform sizes.

**Grades of Diamond Dust.** It is the practice in the Veeder tool-room to divide the diamond dust into five different grades which are designated by the numbers 0 to 4, respectively. This separation of the dust into portions of different fineness is accomplished by a process known as "floating" in olive oil. About one-half pint of oil is used to float fifty karats of diamond dust, and the separation of various portions is accomplished by decanting off the oil after allowing the particles of diamond to settle to the bottom of the container. Fig. 17 shows a set of dishes used for this purpose. Owing to their greater weight, the larger particles of diamond dust will settle more rapidly than the smaller ones. The first separation is made in an ordinary


Fig. 17. Glass Dishes used for "floating" Diamond Dust in Olive Oil. (The illustration does not show the No. 4 Dish)

drinking glass, and after the 50 karats of diamond dust have been thoroughly stirred in the olive oil, two minutes is allowed for the No. 0 particles to settle. Then the oil is decanted off into the No. 1 bowl in which three minutes' time is allowed for the No. 1 particles of diamond to settle before the oil is decanted off into the No. 2 bowl.

This process is repeated for making the three following separations, a period of ten minutes being allowed for the No. 2 sized particles to separate, twenty-five minutes for the No. 3 size, and forty minutes for the No. 4 size. Naturally the condition of the diamond dust used for charging laps will vary according to the work to be done, but at the Veeder shop practically all the lapping is done by either the No. 2 or No. 3 size. Occasionally, use is made of the No. 1 size of dust, but the majority of the particles of this size are returned to the pestle along with all of the No. 0 size so that they may be recrushed and reseparated. Similarly, most of

the No. 4 size dust is too fine to be of use and so, with the exception of the very small amount which may occasionally be utilized for the finest classes of lapping, this portion of the crushed diamonds is discarded. Attention is called to the fact that in making this separation, the olive oil is never used more than once as, even after the No. 4 size of dust has been removed, there still is considerable residue left in the oil; if used repeatedly, it would become so heavily charged with this fine dust that the settling of the larger sized particles would consume a much longer time.

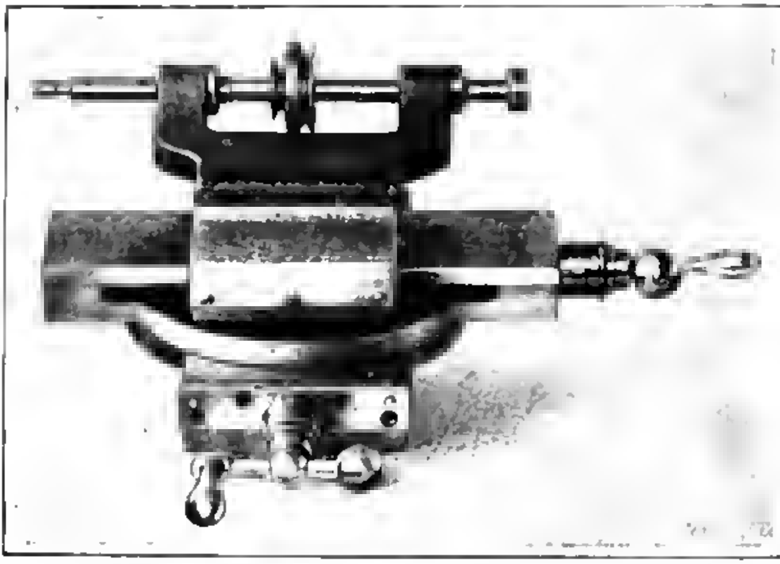


Fig. 18. Slide Spindle Grinding Attachment for the Bench Lathe

**Lapping Accurate Holes.** In lapping operations, one of the conditions which must be carefully guarded against is to avoid having the holes formed with what is known as a "bell mouth." There are several important precautions that must be taken to avoid producing such a defect in the work, one of which is to charge all of the diamond dust into the lap so that it is an integral part of the lapping tool, and not to apply a mixture of diamond dust and oil to the lap while it is in action. In the case of emery and other classes of abrasive, this method is permissible because the cutting action is not nearly so rapid, but in the case of diamond

dust the application of a mixture of the abrasive and oil to a lap would result in piling up diamond dust at each end of the opening, as the lap is reciprocated back and forth through the hole, and thus tend to produce a more rapid cutting action at the two ends of the hole than would occur at other portions, and make the hole bell-mouthed.

Another important condition is to use a lap which has the actual working surface considerably shorter than the length of the hole to be lapped. The lapping operation is performed with the work supported by a spindle fixture on a bench lathe and the lap mounted in a slide spindle grinding attachment shown in Fig 18. With a lap of short length, greater precision can be obtained because it is easier to attain a high degree of uniformity in the cutting action of such a lap. If the length of a lap were made equal to or even greater than, the full length of the hole, so that reciprocation of the tool was unnecessary, the variations in the charging and the consequent rapidity of cutting action would make it difficult to obtain uniform results. The use of a slide spindle grinding attachment on the bench lathe is desirable for several reasons, chief among which are the convenience with which the lap may be reciprocated back and forth through an opening in the work and the ease with which the lap may be recharged when necessary.

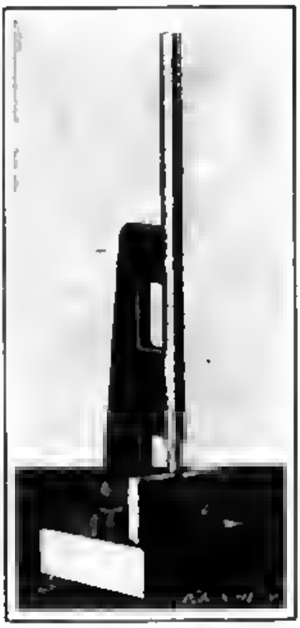


Fig. 19. Fixture for recharging Lap held in Slide Spindle

It is a matter of general knowledge that the abrasive in a grinding wheel tends to become dull or to tear out of the bonding material. Similarly, the points of the abrasive in a lap become dull or the particles pull out of their anchorage in the metal. In either case, recharging is necessary at

regular intervals, and this is accomplished by following a procedure similar to that explained for charging a new lap. But in a lapping operation, it is of the utmost importance to maintain uniform alignment between the lap and the work, and if it were necessary to remove the lap from the spindle for recharging, difficulty might be experienced in resetting it in the original position. With a slide spindle attachment, however, it is only necessary to remove a collar and pull the spindle through its bearings so that the entire spindle and the lap mounted in it may be handled as a unit.

**Recharging End Face of Lap.** Fig. 19 shows a fixture used for holding a spindle and lap while recharging the end face of the lap. Here the use of a hammer is not required because the diamond dust is placed on the hardened block *A* and the spindle is slid up and down in the vertical vees *B* of the fixture so that its weight may impart the necessary momentum to cause the diamond dust to penetrate the end face of the lap when it comes into engagement with the hardened steel block on which the diamond dust is held. When recharging a radial lap, the hammer would be used for forcing the dust in the surface, in the manner previously explained in connection with the description of charging steel laps.

## CHAPTER II

## ABRASIVES, LUBRICANTS AND LAPPING MATERIALS

THE results of a series of tests conducted to determine the cutting properties of abrasives when used with different lapping materials and lubricants, were described in a paper presented before the American Society of Mechanical Engineers. In connection with these tests a special machine was used, the construction being such that quantitative results could be obtained with various combinations of abrasive, lubricant, and lap material. These tests were confined to surface lapping. In the selection of the abrasive—both as to kind and size of grain—the metal of which the lap is made, the lubricant, and the lapping pressure, there is, of course, a wide range of possible combinations. The object of the experiments was to secure reliable data on the following points:

1. The relative efficiencies of the different abrasives.
2. The relative efficiencies of different lubricants.
3. The rate of cutting with laps made of cast iron, soft steel, and copper.
4. The wear of the laps, compared with each other and with the amount of steel ground off each.
5. The effect of pressure on the rate of cutting.
6. The rate of cutting by the wet and the dry methods.

**Construction of Testing Machine.** The testing machine was equipped with a motor-driven lapping plate and a suitable holder for applying the test piece to the revolving plate. This plate was of circular form and was mounted at the top of the vertical spindle, so that it revolved in a horizontal plane. The holder for the test piece was arranged to reciprocate between the center and the outer edge of the lapping plate. The test piece was held against the lapping plate by the pressure of suitable weights, so arranged as to follow up the wear of the test piece with practically no friction.

It was essential to have a uniform distribution of the abrasive charge over the surface of the plate. Centrifugal force was depended upon to work the charge from the center of the plate outward, and by means of a mechanically operated wiping device the abrasive was kept distributed over the surface of the lap. The test pieces were of hardend tool steel, cylindrical in form, the diameter being 5/8 inch and the length 1/2 inch.

**Abrasives Tested.** It was not the intention to test all the different abrasives on the market, three being selected as being representative; namely, "Naxos" emery, carborundum, and alundum. Abrasive No. 150 was used in each case, and seven different lubricants, five different pressures, and three different lap materials were employed. The lubricants were lard oil, machine oil, kerosene, gasoline, turpentine, alcohol, and soda water.

Starting a series of tests, say with emery as the abrasive and with a cast-iron lap, the first test was made with lard oil and with a pressure of 5 pounds per square inch on the specimen. The pressure was then increased to 10 pounds per square inch, other conditions remaining the same, and another run made. The pressures were then increased to 15, 20, and 25 pounds, giving a group of five runs with lard oil. Machine oil was then substituted for lard oil and a like group of tests made, after which tests were made with the other lubricants in the same way. This gave for the cast-iron, emery-charged lap a series of thirty-five tests. Carborundum was next substituted for emery and the same number of tests repeated. This was followed by a like series with alundum, making the total number of tests with a cast-iron lap 105.

The cast-iron lap was then replaced by one of steel and a second series of 105 tests run with the steel lap. This was followed by a like series with the copper lap. Therefore, for making comparisons of the action of the three abrasives and also for the three lap materials, cast iron, copper, and steel, there were 105 tests of each.

Before starting a test run, the charge of abrasive and lubricant was distributed as uniformly as possible over the surface of the lap. The test was continued until the crank

which moved the test piece over the plate had made 4000 revolutions. At the end of 500 revolutions the specimen was removed, cleaned with gasoline, and weighed. This was repeated at the end of the next 500 revolutions, and then for each 1000 revolutions until the 4000 revolutions were completed.

**Effectiveness of Lapping Lubricants.** The action of the different lubricants was found to depend upon the kind of abrasive and the lap material. A summary of the results obtained with different lubricants follows:

*Lard and Machine Oil.* On account of their similarity of action, lard and machine oil will be considered together The test showed that lard oil, without exception, gave the higher rate of cutting and that, in general, the initial rate of cutting was higher with the lighter lubricants but fell off more rapidly as the test continued. Both the highest and lowest results of the entire series of tests were obtained with these two lubricants. The lowest was obtained with machine oil, when using an emery-charged cast-iron lap, lard oil giving slightly better results. The highest results were obtained with lard oil and a carborundum-charged steel lap.

*Gasoline and Kerosene.* On the cast-iron lap, gasoline was superior to any of the lubricants tested. It was not so good on copper and still less on steel. Considering all three abrasives, the relative value of gasoline, when applied to the different laps was as follows: Cast iron, 127; copper, 115; steel, 106. Kerosene showed more nearly the characteristics of gasoline than of the heavier oils. Like gasoline, it gave the best results on cast iron and the poorest on steel. It did not work very well with carborundum on a copper lap. During the entire series of 315 tests, there were but two instances in which the values obtained by carborundum were not higher than the values obtained when using emery, and these two were with gasoline and kerosene on a copper lap.

*Turpentine and Alcohol.* There was no evidence to show that turpentine possessed a superior advantage over the other lubricants. On any lap it was found to do good work with carborundum. With emery it did fair work on the

copper lap, but with the emery on cast-iron and steel laps, it was distinctly inferior.

Alcohol, in some ways, acted very much like turpentine, since it gave the lowest results with emery on the cast-iron and steel laps. Alcohol and turpentine were the only two lubricants that gave any evidence of having a solvent or chemical action on the abrasive, and these with emery only.

*Soda Water.* Soda water gave reasonably good results with almost any combination of lap and abrasive; thus, while it was seldom the best, it was never the worst. Soda water did its best work on the copper lap and the poorest on the steel lap, although there was little difference between the results with the cast-iron and steel laps. On the cast-iron lap, soda water was better than machine or lard oil, but not so good as gasoline or kerosene. Soda water, when used with alundum on the copper lap, gave the highest results of any of the lubricants used with that particular combination. While soda water is objectionable, owing to the sticky residue and the hard crusty substance which it forms when dry, as far as the results go and as to first cost, it should rank ahead of turpentine and alcohol.

**The Lapping Abrasives.** As to the qualities of the three abrasives tested, it was found that carborundum usually began at a lower rate than the other abrasives, but when once started its rate was maintsined better. The performance gave a curve that was more nearly a straight line. The charge or residue as the grinding proceeded remained cleaner and sharper and did not tend to become pasty or muck-like as is so frequently the case with emery.

Alundum, both as to its rate of cutting and cleanliness of residue, was found in general to be intermediate between carborundum and emery. Taking the total amount of steel in milligrams ground from the specimens with each of the abrasives as a base for comparison, they stand as follows: Carborundum, 84,507; alundum, 71,944; emery, 61,682. These figures are for all three laps. When using a copper lap, carborundum showed only a slight gain over cast-iron and steel laps, whereas when emery and alundum were used, the gain was found to be considerable.

These tests indicated throughout that for each different combination of lap and lubricant there is a definite size of grain that will give the maximum amount of cutting. With all the tests, excepting when using the two heavier lubricants, some reduction in size of grain below that used in the tests (No. 150) seemed necessary before the maximum rate of cutting was reached. This reduction, however, was continuous and soon passed below that which gave the maximum cutting rate.

**Comparison of Laps.** Each lap consisted of a cast-iron backing plate faced with the proper material. The cast-iron plates were of a good grade of foundry iron but no attempt was made to secure a special mixture. The copper lap was made of plate copper 1/4 inch thick, and the steel lap of the same thickness was made of fire-box steel. The surfaces of the steel and cast-iron laps were finished by grinding. The hardness of the different laps, as determined by the scleroscope, was, for cast iron, 28; steel, 18; copper, 5. The total amount ground from the test pieces with each of the three laps was, with cast iron, 67,511; with steel, 67,865; with copper, 82,757 milligrams. These figures show that taking the whole number of tests as a standard, there is scarcely any difference between the steel and cast iron but that copper has somewhat better cutting qualities. However since there is a great difference between the highest and lowest values obtained with each lap, it would seem more logical in comparing the relative merits to refer to the highest values obtained with each. Comparing them on this basis, they stand in the following order:

Steel, with carborundum and lard oil, 4649.

Copper, with carborundum and lard oil, 4540.

Cast iron, with carborundum and gasoline, 4520.

These figures show that with the proper abrasive and lubricant, steel and cast iron are as good for all practical purposes as copper.

One of the remarkable facts shown by the tests is the great differences in wear of laps, both as regards the material from which they are made and wear due to the different abrasives. The wear on all laps was about twice as fast

with carborundum as with emery, while with alundum the wear was about $1\frac{1}{4}$ times that with emery. On an average the wear of the copper lap was about three times that of the cast-iron lap. This is not absolute wear, but wear in proportion to the amount ground from the test pieces.

**Lapping Pressures.** Within the limits of the pressures used, that is, up to 25 pounds per square inch, the rate of cutting was found to be practically proportional to the pressure. That this is not strictly true is because of the change in the size of the abrasive grains as the lapping operation proceeds. There is an increasing rate for a time and then a decreasing one; the greater the pressure the quicker this change. During the early part of a run the rate of cutting was not only increased by additional pressure but there was another increment due to the change in size of grain. After the maximum rate had been reached, the cutting was not quite proportional to the pressure. The higher pressures of 20 and 25 pounds per square inch were not so effective on the copper lap as on the other materials.

**Wet and Dry Lapping.** There are two methods of using a surface lap which, for want of better definitions, will be termed the "wet" and the "dry" methods. With the wet method there is a surplus of oil and abrasive on the surface of the lap. As the specimen being lapped is moved over it there is more or less movement or shifting of the abrasive particles. The action may be conceived to be somewhat as follows: A particle becomes embedded in the softer surface of the lap, it remains stationary for a while, but is finally dislodged by friction or change in direction of the rubbing surface. It then rolls around for a while, only to lodge again and have the process repeated. Meanwhile the grains of abrasive are being broken up into smaller sizes, their sharp edges and corners worn away, and the cutting effect grows less, until it becomes necessary to recharge the lap with fresh material.

With the dry method, the lap is first charged by rubbing or rolling the abrasive into its surface. All surplus oil and abrasive is then washed off, leaving a clean surface, but one that has embedded uniformly over it small particles of the

abrasive. It is then like the surface of a very fine file or oilstone and will cut away hardened steel that is rubbed over it. While this has been termed the dry method, in practice the lap surface is kept moistened with kerosene or gasoline. This is for the purpose of preventing small spots of steel, called "birds' eyes," building up on the lap surface; but there is not enough lubricant applied to "float" the piece being lapped.

Among mechanics there is some difference of opinion as to whether the cutting is more rapid with the wet or the dry method. By advocates of the dry method it is pointed out that in this the abrasive is permanently embedded in the lap surface, there is actual contact between the abrasive and the steel specimen, there is no floating on an oil film, no rolling on loose particles, that the cutting action is more nearly true, and hence more rapid than when these conditions fail to obtain.

**Experiments on Dry Lapping.** Experiments on dry lapping were carried out on the cast-iron, steel, and copper laps used in the previous tests and also on one of tin made expressly for the purpose. Like the others, the tin lap was made up of a cast-iron backing plate provided with a facing of block tin about 1/4 inch in thickness.

Carborundum alone was used as the abrasive and a uniform pressure of 15 pounds per square inch was applied to the specimen throughout the tests. In dry lapping much depends on the manner of charging the lap. The first tests were made on the steel lap, charged by rubbing the abrasive into the surface with a cast block 3 inches by 2 inches. With a small quantity of carborundum (F) and lard oil, the surface was worked down until of a uniform slaty color and free from deep scratches or marks left by the grinder. It was then washed clean with gasoline and used perfectly dry. Next the plate was charged in the same way, but instead of being washed with gasoline the surface was simply wiped clean with waste. This left the plate practically dry but with a light film of oil adhering to its surface.

The results of these tests show that with a lap perfectly clean and dry the rate of cutting is reduced quite rapidly

after the first 100 revolutions. At the end of 500 revolutions, the total amount ground from the specimen was 10.6 milligrams. When the plate was wiped clean and not washed with gasoline, the amount ground off at the end of 500 revolutions was 63 milligrams or about six times as much as with the plate perfectly dry.

Experiments demonstrated that between these two extremes, results of any magnitude could be obtained, depending on how thoroughly the free abrasive was removed from the lap surface. When the lap is simply wiped clean there still remains a film of oil over its surface and this carries a certain amount of free abrasive. For all subsequent tests the plates were washed thoroughly clean, in order that there should be no variation in results due to a varying amount of free abrasive on the lap surface.

**Wet and Dry Method Compared.** Obviously with so many different results, a comparison between the various methods of wet and dry lapping is more or less unsatisfactory. With dry lapping, the rate of cutting decreased much more rapidly for the first 100 revolutions than with the wet method. In making comparisons, however, it seems fair to consider the amounts ground off during the first 100 revolutions. Moreover, the best result obtained with each lap was taken as the basis of comparison. It was found that with a tin lap charged by rolling No. 150 carborundum into the surface, the rate of cutting, when dry, approached that obtained with the wet method. With the other lap materials, the rate with the dry method was about one-half that of the wet method.

**Conclusions of Lapping Tests.** The principal facts of the results of these tests are here summarized:

1. The initial rate of cutting is not greatly different for the different abrasives.

2. Carborundum maintains its rate better than either of the others, alundum next, and emery the least.

3. Carborundum wears the lap about twice as fast, and alundum 1¼ times as fast, as emery.

4. There is no advantage in using an abrasive coarser than No. 150.

5. The rate of cutting is practically proportional to the pressure.

6. The wear of the laps is in the following proportions: cast iron, 1.00; steel, 1.27; copper, 2.62.

7. In general, copper and steel cut faster than cast iron, but where permanence of form is a consideration, cast iron is the superior metal.

8. Gasoline and kerosene are the best lubricants to use with cast-iron lap; kerosene, on account of its non-evaporative qualities, being first choice.

9. Machine and lard oil are the best lubricants to use with a copper or steel lap. They are least effective on a cast-iron lap.

10. For all laps and all abrasives (of those tested), the cutting is faster with lard oil than with machine oil.

11. Alcohol shows no particular merit as a lapping lubricant.

12. Turpentine does fairly good work with carborundum, but in general is not so good as kerosene or gasoline.

13. Soda water compares favorably with other lubricants. Taken as a whole, it is slightly better than alcohol and turpentine.

14. Wet lapping is from 1.2 to 6 times as fast as dry lapping, depending on the material of the lap and the manner of charging.

## CHAPTER III

### POLISHING METHODS

In manufacturing various metal products, any of several different reasons may make it necessary to polish some of the parts. This may be done in order to improve the appearance of the surface of the metal from which a piece is made, it may be done for the purpose of preparing the work to receive some such finish as nickel plate, or certain other reasons may make it necessary to perform a polishing operation. The kind of surface that is finally produced before the product is shipped to the user will depend largely upon the conditions under which it is to be used. For instance, machinists' scales, squares, micrometers, etc., are ordinarily finished by simply polishing the steel in order to give a uniform surface of good appearance, and one on which the graduations and figures may be easily read. Another common method of finishing is to polish the surface of the metal and then apply a coat of lacquer, in order to avoid deterioration through rust or corrosion of the metal. Still another commonly used method of finishing a polished surface is to apply a coat of nickel plate or some form of chemical treatment. Where any of these general methods is employed, the final finish produced on the work is accomplished by either electrolytically depositing nickel or some other metal, or by the action of chemical reagents upon the surface of the work. Regardless of the kind of finish that is applied to the metal, it is important to have a uniformly polished surface and one which is chemically clean, because in the presence of grease or any other foreign matter adhering to the surface that is to be treated by one of these methods, it will be found impossible to apply the nickel plate or the chemical treatment with sufficient uniformity to produce work of a satisfactory appearance.

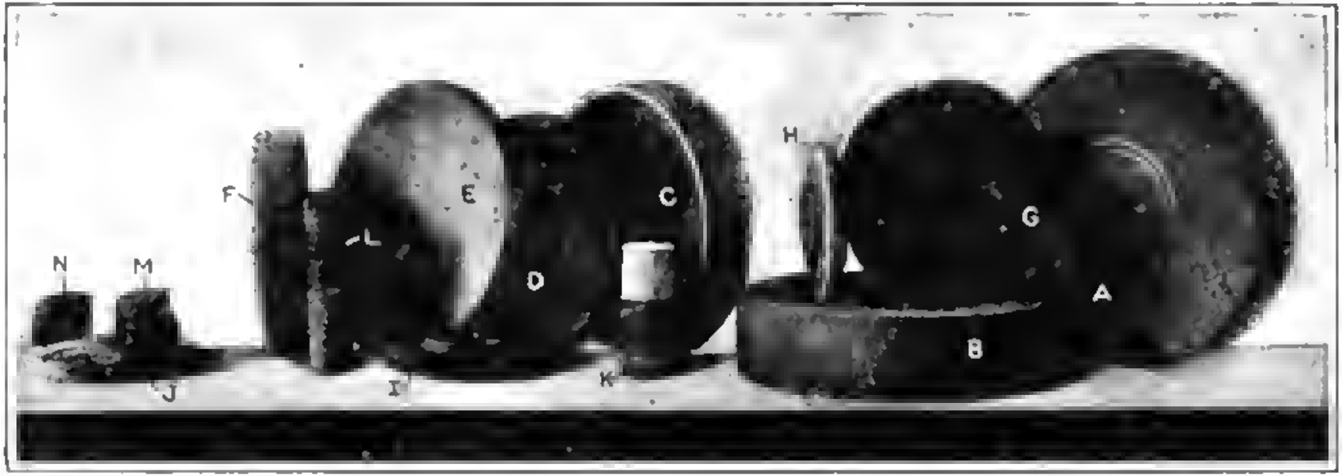



Fig. 1. (A) Corundum Grinding Wheel; (B) Set-up Wheel with Leather Segments mounted in Steel Frame; (C, D and F) Various Types of Set-up Wheels with Leather Face mounted on Wooden Disk; (E) Plain Felt Wheel; (G) Rag Wheel with Abrasive glued to the Polishing Surface; (H) Polishing Wheel with Face trued up to conform to Contour of Work; (I and J) Sheepskin Wheels, to be charged with Flour of Emery, Rouge, etc.; (K, L, M, and N) Grease and Fine Abrasive Material prepared in Sticks for Application to Polishing Wheels

**Condition of a Polished Surface.** The best idea of the results of successive polishing operations will be obtained by examining the surface of the work under a magnifying glass, after taking each of the steps in polishing. Any machined surface of the work will be covered with a series of ridges and scratches running in the direction in which the piece

Table I. Methods Used by Royal Typewriter Co. for Performing Polishing Operations

| Kind of Work to be Polished | Operation No. | Type of Polishing Wheel | Kind of Abrasive Used to Charge Wheel | Coarseness of Abrasive |
|---|---|---|---|---|
| Rough castings to be japanned | 1 | Grinding wheel | Carborundum | No. 30 medium grade |
| | 2 | Leather-faced set-up wheel | Emery | No. 36 |
| | 3 | Loose rag wheel | Emery | No. 60 |
| Irregular shaped work to be japanned | 1 | Rag wheel sewed to circumference | Emery, glued to face of wheel | No. 60 |
| | 2 | Loose rag wheel | Emery | No. 90 |
| Small iron castings | 1 | Leather-faced set-up wheel | Emery | No. 36 |
| | 2 | Loose rag wheel | Emery | No. 60 |
| Bronze castings | 1 | Loose rag wheel | Emery | No. 150 |
| Steel stampings[1] | 1 | Loose rag wheel | Emery | No. 150 |
| German silver | 1 | Tumbling barrel | No. 0 pumice and water for 24 hrs. | |
| | 2 | Wood-lined tumbling barrel and steel balls | 10 lbs. white soap chips and 2 pails of water to a barrel: 10 hrs. | |
| | 3 | Nickel-plating barrel for 3 hrs. | | |
| German silver | 4 | Wood-lined tumbling barrel and steel balls | 10 lbs. white soap chips and 2 pails of water to a barrel: 3 hrs. | |
| | 5 | Steam-heated tumbling barrel | Heated sawdust to dry work | |
| Work to be Nickel-plated | 1 | Leather-faced set-up wheel | Emery and buffing grease | No. 150 |
| | 2 | Leather-faced set-up wheel | Emery and buffing grease | No. 200 |
| | 3 | Leather-faced set-up wheel from Operation 3. with grease wiped off | Emery | No. 200 (This operation "fines" work and produces a high polish.) |
| | 4 | Tampico brush | "Emory paste" (a mixture of tallow or paraffin and emery) | No. 150 emery (This operation rounds corners of work so that nickel-plate will not wear off.) |
| | 5 | Leather-faced set-up wheel | Emery greased with beeswax | Flour of emery |
| | 6 | Loose rag wheel to buff copper-plated surface | Lime | |
| | 7 | Loose rag wheel to polish nickel-plated surface | Lime[2] | |

[1] Stampings must be carefully washed to remove all traces of grease before polishing.

[2] If the nickel is too rough to buff well, charge wheel with "white diamond" or rouge. Note: The above recommendations refer to the polishing of well-machined parts. Rough or imperfectly machined pieces would require different treatment.

was passed under the cutting tool. Their coarseness will naturally vary according to the care taken in the final machining operation, but in any case it will be found impossible to produce work which will not show such defects when examined through a powerful lens. The purpose of polishing is to rub down these ridges, in order to bring the surface to a condition approximating a perfect plane. Where the work is examined in each of the successive stages through which it passes in machining and polishing, it will be quite evident that the coarseness of the ridges and valleys is reduced at each step; but in this connection, attention is called to the fact that even where the greatest care is taken in the final polishing, it is never possible to produce a surface which is not covered with a mass of scratches that will be perfectly visible if the work is examined through a glass of sufficient strength. In a series of polishing operations, it is the general practice gradually to reduce the coarseness of the abrasive that is used, so that the surface of the work not only approaches a perfect plane, but also has the scratches brought down to a size which represents the minimum that can be obtained under the best conditions.

**Polishing to Suit the Work.** All experienced mechanics know that abrasives are made in standard grades of coarseness which cover a wide range and that grinding wheels charged with these abrasives are held together by bonding mediums which may be selected to produce wheels conforming to various standards. In the polishing room, grinding wheels are used for the performance of a first operation where the work is of such a nature that there is a considerable amount of excess metal to be removed from the surface which is to be polished. After the preliminary operation has heen performed with a grinding wheel, there are several methods of performing subsequent operations. The usual practice is to employ a series of "set-up" wheels, each of which is charged with a finer abrasive than that used in making the wheel previously used, and then to obtain a final polish through the use of a rag wheel or a brush wheel, charged with some such abrasive as powdered chalk or rouge. Success in polishing depends largely upon the selec-

tion of proper grades of abrasive for performing the rough, intermediate and final polishing operations. Detailed information in regard to suitable classes of abrasives to employ for the performance of polishing operations on cast iron, steel, copper, brass, bronze, nickeled surfaces, copper-plated surfaces, and other classes of work, will be obtained by reference to Tables 1 and 2. The directions given refer to

**Table 2. Recommended Practice in Polishing on Abrasive Belt Machines**

| Kind of Work to be Polished | Operation No. | Abrasive Used to Charge Belt | Coarseness of Abrasive |
|---|---|---|---|
| Cast iron | 1 | Crystolon | No. 70 |
| | 2 | Crystolon | No. 120 |
| | 3 | Crystolon | No. 220 (for work to be nickel-plated) |
| | 4 | Crystolon | No. 220, greased (for work to be lacquered without nickel-plating) |
| Steel | 1 | Alundum | No. 70 to 90 |
| | 2 | Alundum | No. 120 to 150 |
| | 3 | Alundum | No. 220 (for work to be nickel-plated) |
| | 4 | Alundum | No. 220, greased (for work to be lacquered without nickel-plating) |
| Brass | 1 | Alundum | No. 320 |
| | 2 | Felt belt charged with Tripoli | |
| Copper | 1 | Crocus | |
| | 2 | Felt belt charged with Tripoli | |

Note: The above recommendations refer to the polishing of well machined parts. Rough or imperfectly machined pieces require different treatment.

the polishing of well machined parts, and not to roughly machined pieces.

**Making Polishing Wheels.** Mention has been made of the fact that where there is a lot of excess metal to be removed from the work to be polished, a preliminary operation is performed with a regular grinding wheel of suitable grade and grain. Such a wheel requires only an occasional dressing with a diamond or some other type of wheel-truing device in order to remove the glaze from its surface and

expose a fresh layer of abrasive which has sharp cutting edges. A grinding wheel is used in this way only where the surface to be polished is very rough. Next in order of use in reducing a rough surface to a final polish comes the so-called "set-up" wheel, which may be made in either of two general ways. A common form of construction is to make the wheel of a wooden disk with a leather surface attached to its periphery. Where this form of wheel construction is used, the leather is glued to the wheel and the ends are spliced on an angle, according to the method commonly employed for making an endless leather belt with a cemented joint. It is also highly important for the lapping of these splices to be arranged as shown in Fig. 2, so that the work runs over the top of the lap without a tendency to catch the edge of the leather and open the splice. A patented form of set-up wheel is made by Divine Bros., of Utica, N. Y. The body of this wheel is made of sheet metal instead of wood, and it is of somewhat the same general form of construction as a steel belt pulley. The leather surface around its periphery is built up from laminations of leather laid edgewise, and secured to the wheel by lugs provided at the bottom of each leather segment.

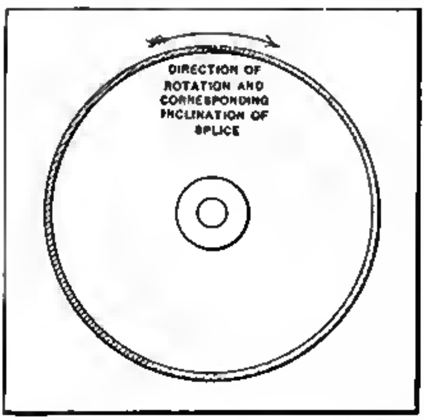


Fig. 2. Method of splicing Leather Face on Set-up Wheel

**Preparing Set-up Wheel for Polishing.** Regardless of the way in which the body and leather surface at the periphery of a set-up wheel are constructed, the same general practice is employed in preparing a wheel of this type for polishing. An abrasive cutting surface is provided on the leather by first mounting the wheel on a mandrel, and revolving it as shown in Fig. 3, so that a coat of glue may be applied to the leather. Then, while the wheel is still carried on the

mandrel, it is transferred to a shallow trough filled with abrasive of the desired coarseness, and the wheel is rolled as shown in Fig. 4, so that the glue-covered surface may take up the abrasive, which adheres over the entire cutting face of the wheel. It is then necessary to allow a sufficient length of time for the glue to dry, so that it will hold the abrasive securely in place on the wheel.

Before this set-up wheel can be used for polishing, it

Fig. 3. Applying Glue to the Face of a Set-up Wheel

must be trued in much the same way as a regular grinding wheel, a diamond or one of the commercial types of wheel-dressing tools being used for the purpose. The conditions under which the polishing wheel is to be used will naturally govern the way in which the dressing is done. Many wheels are trued up with a flat face, where polishing is to be done on broad surfaces, and others are dressed to a contour corresponding to the outline of the surface on the work that

is to be polished. When a new set-up wheel is to be used for the first time, it is slowly rotated on the grinding stand and a stick of hard wood is pressed against the abrasive face of the wheel. The purpose of this treatment is to break up the foundation of glue beneath the abrasive, thus bringing the face of the wheel into a condition where it will yield under pressure and adapt itself to slight irregularities on the work to be polished. A wheel made in this way has

Fig. 4. Rolling Glued Set-up Wheel in Abrasive

a face which is slightly elastic, because the leather foundation to which the abrasive is secured acts as a cushion, and also because the coating of glue and abrasive put on the face of the wheel is not subjected to pressure, as in the case of a grinding wheel, and so is left in a somewhat springy condition. As a result, the set-up wheel is able to conform, to a certain extent, to the shape of a piece of work which is pressed against its face.

**Securing Abrasive Material on Set-up Wheels.** Any good quality of glue may be used for securing abrasive to the face of a set-up wheel. It will usually be found most satisfactory to buy this glue dry and prepare it for use at the plant. The first step is to allow the glue to steep in cold water over night, a sufficient amount of water being mixed with the glue to bring it to about the consistency of dough. The glue-pot is provided with an upper compartment in which the glue is placed and heated by steam in order that it may melt and run down into a lower compartment. Too much care cannot be exercised in preparing the glue, because the use of a satisfactory quality of glue has an important influence in determining the quality of the polished surfaces that are produced by the wheel. The glue must be smooth and quite free from lumps, so that it may be spread evenly over the leather face of the wheel on which the abrasive is to be applied. The consistency of the glue should be varied somewhat, according to the coarseness of the abrasive to be used. Very fine abrasives are best held by thin glue, while a thicker glue will be required to hold coarser grained abrasives on the wheel.

**Preparing Set-up Wheels for Subsequent Use.** Everyone who has had experience in operating grinding machines knows that the wheels must be dressed to remove the glaze which forms on the surface of the wheel, and to expose a fresh layer of abrasive with sharp cutting edges. Repeated dressing of this kind causes a substantial reduction in the diameter of the wheel. The same reasons which require a grinding wheel to be dressed make it necessary to give similar attention to a polishing wheel; but as the covering of abrasive on such wheels does not have much depth, it soon becomes necessary to apply a fresh cutting surface to the wheel. This is done by first removing the worn-out abrasive, and then applying a new cutting surface according to the method which was described for preparing a new set-up wheel. For removing the worn-out abrasive, the wheel is mounted on an arbor, as shown in Fig. 5, and this arbor is placed in the bearings of a special stand, beneath which there is a tank filled with water. The machine operator

then dips up a panful of this water, and pours it slowly on the set-up wheel, as it is revolved, and proceeds to scrub the face of the wheel with a piece of broken grinding wheel. In this way the accumulation of abrasive and glue is removed, after which the wheel is scrubbed with a cloth to clean the leather surface. It is then covered with glue and rolled in a trough of abrasive of the proper grade, in just the same way that a new wheel is prepared.

Fig. 5. Applying Water to Set-up Wheel before scrubbing off Abrasive

In the polishing room of the Royal Typewriter Co., in Hartford, Conn., it is the practice to have all of the work of preparing wheels done by men who give their entire time to this job, and hence acquire a greater degree of dexterity than would be possible if each polisher were required to prepare his own wheels for subsequent use. As the life of a polishing wheel is quite limited, each man is furnished with several wheels, in order that he can send one of them to be re-surfaced and start using another wheel without delay.

Each of the men in the polishing room is furnished with a regular set of wheels, and racks are provided on which each man is allowed a definite amount of space marked with his time-clock number. Fig. 6 shows one of these racks, and also an arbor press that is used by the polishers to force the arbor into or out of the wheel, at the time they are starting or completing the work of re-surfacing.

Fig. 6. Rack used in Polishing Room for storing Polishing Wheels

**Felt and Rag Wheels for Final Polishing.** As the names imply, felt wheels and rag wheels are made of the materials from which they are named. Both of these types of wheels are built up by sewing together disks of felt, or circular pieces of cloth. There is a considerable variation in the practice of making wheels of this type, although the general method of procedure is uniform in all cases. In the case of cloth wheels, the usual method is to make up bunches of

cloth of about ¼ inch in thickness, with all of the pieces of cloth in a bunch securely sewed together for a distance of about 2 inches from the center. From this point to the periphery, the individual pieces of cloth which make up one of these bunches are left loose. A rag wheel is made by assembling together on an arbor the proper number of bunches to give the required face width. It will be quite apparent that when a rag wheel is at rest, it would not have sufficient stiffness to enable the periphery of such a wheel to perform a polishing operation; but when the wheel is driven at a rotative speed which corresponds to a peripheral speed of from 5000 to 7500 feet per minute, it will be apparent that the action of centrifugal force on each of the cloth disks composing such a wheel causes these disks to stiffen up and gives them plenty of resiliency for polishing the work. Felt and rag wheels used for final polishing operations are usually charged with some very fine abrasive such as rouge. Detailed information concerning the abrasives to use on different polishing jobs is presented in tabular form.

**Keeping Work Clean while Polishing.** In one of the preceding paragraphs, attention was called to the fact that where a polished surface is to be nickel-plated or subjected to some method of chemical treatment, it is necessary to have the work perfectly clean before such a treatment is applied. This point is now repeated, in order that the previous statement in regard to the importance of cleanliness may not be confused with another condition which must be fulfilled if successful results are to be obtained in polishing, namely, that the greatest care must be taken not to allow grease or dirt to drop on the polishing wheel or work during the operation. Where this precaution is not followed great trouble will be experienced through having long smears produced across the polished surfaces, which will destroy the appearance of the product. An explanation of the way in which such defects are produced may well be given in connection with a description of the action of a polishing wheel. During the preliminary oper-

ations in polishing, where coarse abrasives are used, the individual grains of abrasive cut off chips of metal; but in performing the final operations by wheels charged with the very finest abrasives, the action is believed to be one of rubbing down the surface of the metal to a uniform level, instead of actually removing chips.

At the high speeds at which a polishing wheel is driven, it is the theory of experienced polishers that the wheel has a tendency to remove the tops of the microscopic ridges on the work, to which reference has been made, and press the metal so removed down into the spaces between adjacent ridges, thus reducing the work to a plane surface. If any grease or dirt drops on the wheel or work, it will be apparent that this shifting of the metal over the surface of the work will result in amalgamating the foreign matter with the metal, thus producing a smear of unsightly appearance. A distinction must be drawn, however, between the undesirability of having grease drop on the work, and a quite general practice in polishing rooms of applying grease to the surface of the polishing wheel in order to produce a very smooth finish. One kind of grease used for this purpose consists of a mixture of two parts of hide scrapings to one part of paraffin, although a perfectly satisfactory grease may be bought under the commercial name of "buffing grease," or "buffing tallow." The reason that applying this grease to the wheel does not produce smears on the work is due to the fact that the grease is uniformly distributed over the wheel and work, instead of being applied merely at one point. It is the practice to use a greased wheel for the final polishing operation, as experience has shown that the application of grease to the wheel results in rubbing the work down to a smoother polish than could be obtained from the application of an ungreased abrasive wheel to the work. This practice of greasing the wheel gives it a more uniform cutting action, and prevents the abrasive from making visible scratches on the work. As a result, a greased wheel is able to produce a higher polish.

**Abrasive Belt Polishing Machines.** There is another type of polishing machine which is constantly increasing in popu-

larity as it becomes more generally known to the trade. This is the abrasive belt polishing machine which is built in a number of different types. They all operate on the same basic principle of having a belt charged with abrasive driven over the surface of the work, which is held in contact with the abrasive belt through the application of pressure. Two general principles are employed by the Blevney Machine Co., of Greenfield, Mass., for supporting the endless

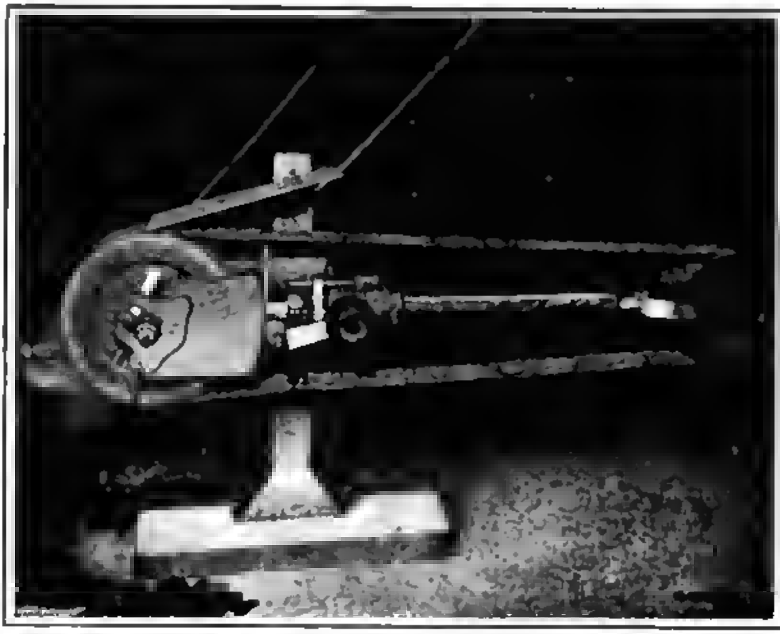


Fig. 7. Abrasive Belt Type of Polishing Machine with a Leather Wheel to support the Polishing Belt

abrasive belt used on these machines, which consists of a fabric charged with an abrasive of a suitable coarseness. This belt would not be strong enough to withstand the pressure with which the work must be applied to the abrasive, unless the belt was properly supported. These two methods of support consist either of having the abrasive belt run over a leather faced wheel which is built up of segments of leather placed edgewise, or of having the abrasive belt backed up by a corrugated leather belt. Machines equipped

with these two types of support for the belt are shown in Figs. 7 and 8, respectively.

**Clearing Cuttings from Abrasive Belts.** Experiments conducted in the laboratories of the Norton Co., of Worcester, Mass., have shown that the abrasive belts used on these polishing machines cut elongated chips from the metal, and that they do not remove the material in the form of dust. It is important to provide for clearing the cuttings from the abrasive belt, because if this were not done, the belt would soon become so heavily charged that it would fail to operate efficiently. The arrangement of the laminated leather wheel or the corrugated leather belt provides for such elimination of cuttings. The way in which these results are accomplished is best shown by the diagrams Figs. 9 and 10, which show enlarged views of a section of the laminated wheel and of the corrugated leather belt, respectively. In the case of the wheel, Fig. 9, it will be apparent that the leather laminations show a tendency to bend backward when the work is pressed against the belt carried by them. This backward bending of the corrugations causes small spaces or pockets to develop beneath the belt, which allow the belt to be depressed sufficiently to form the required amount of chip clearance between the belt and

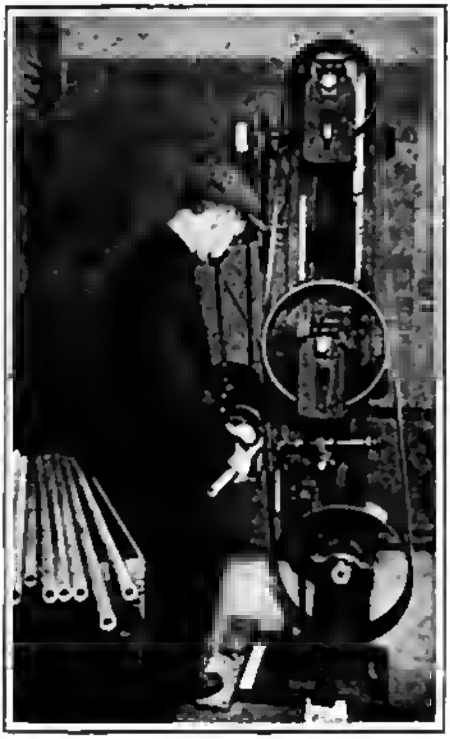


Fig. 8. Abrasive Belt Type of Polishing Machine with a Corrugated Leather Belt to support Abrasive Belt

the work. In this way, the chips are carried along beneath the work, without deeply embedding them in the texture of the belt; and when the belt and chips pass out from under the work, the tension on the belt causes it to straighten out with a snap, thus throwing the chips clear of the belt.

After one of these laminated wheels has been used for some time, a tendency will be shown for the leather laminations to take a permanent set in the direction in which they have been bent backward. If allowed to develop without correction, the amount of this set would assume objectionable proportions. To overcome trouble from this source, provision has been made for lifting the complete unit consisting of the leather cushion wheel, with its spindle and bearings, out of the support in the frame, allowing the operator to reverse the leather wheel on its spindle and replace the unit with a minimum amount of labor. By adopting this practice, the laminations which were formerly bent backward are now leaning toward the front, so that when pressure is applied to the abrasive belt and laminations, they will first be pulled over to the center point and then back to the position indicated by the diagram. Reversals of the wheel can be made with very little loss of time.

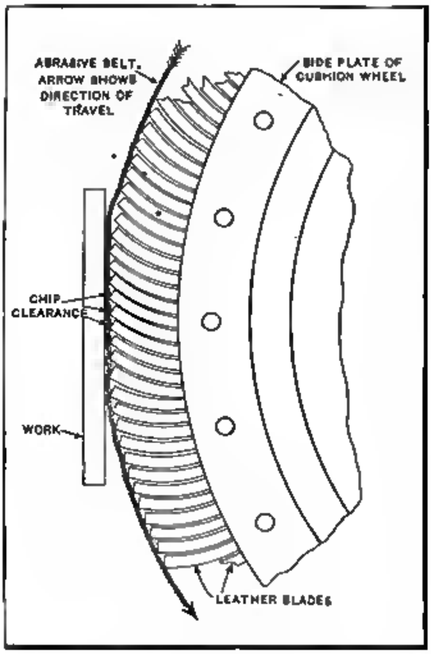



Fig. 9. Principle of Supporting Wheel on Machine shown in Fig. 7.

The corrugated leather supporting belt, shown diagrammatically in Fig. 10, functions essentially the same way, in so far as clearing the chips from the belt is concerned. It will be apparent from the diagram that the corrugations in

this belt enable clearance pockets for the chips to be formed between the abrasive belt and the work. After the belt passes out from under the work, its tension causes the belt to straighten out with a snap and throw the chips clear in the same way that this result was accomplished by the laminated leather wheel.

**Attachments for Abrasive Belt Polishing Machines.** For use on the abrasve belt polishing machines built by the Blevney Machine Co., a number of different attachments are made, which facilitate polishing operations on various special

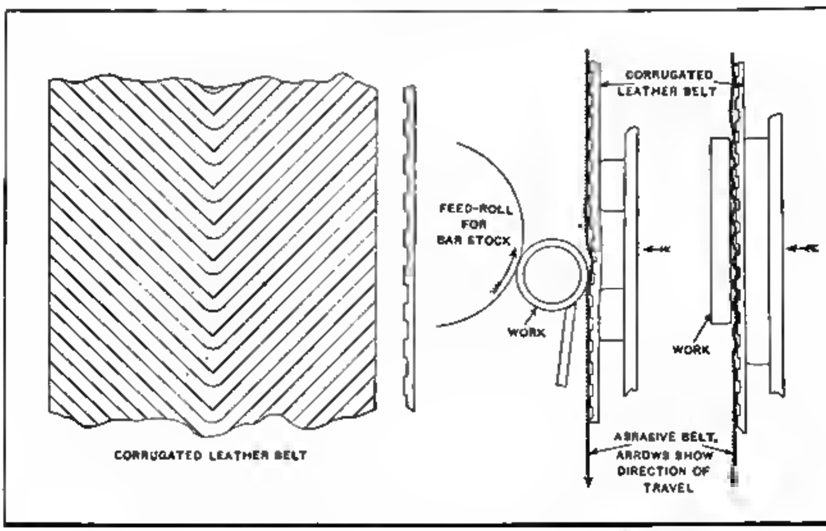



Fig. 10. Principle of Operation of the Corrugated Leather Belt for supporting the Abrasive Belt used on the Machine shown in Fig. 8.

classes of work. These special attachments include feed-rolls for automatically passing cylindrical shaped rods and tubing across the face of the abrasive belt; racks for use in connection with the feed-rolls, to provide for supporting the long pieces of cylindrical work; multiple work-carrying fixtures for holding a number of small or medium sized pieces of work in contact with the abrasive belt, and various forms of work-rests for holding a single piece of work while the polishing operation is performed on it.

**Coarseness of Abrasives Used on Polishing Belts.** In Table 2 there are presented recommendations for polishing opera-

tions on abrasive belt machines. The data in this table give a general outline of practice for polishing several of the most commonly used metals. While a general table recommending the abrasive to be used in polishing will be of assistance to an operator using abrasive belt machines, a knowledge of the work in hand, the kind of metal to be finished and its condition preparatory to finishing is necessary before the selection of the proper abrasive can be made. For instance, rough castings or imperfect parts require a different treatment from well machined pieces, such as articles of steel that are nicely machined and ground and require only the very finest polish, for which one operation would probably be adequate. The table is made up for well machined parts, such as might be produced on an automatic screw machine—pieces that have been given a fairly good finish and which must subsequently be polished.

Crystolon and alundum are recommended as cutting abrasives for ordinary finishing, but where the finest polishing is required and it is necessary to color, such as on nickel and brass work, there are various compositions such as tripoli, crocus, white polishing composition, Vienna lime and rouges. Tripoli is made with cutting, polishing and coloring qualities, and is used on steel, cast iron, brass, etc., for fine polishing. Crocus is especially suited for the smooth finished surface on cast iron and steel, and is sometimes used on brass, although it has a tendency to discolor this metal. Crocus is used a great deal by stove manufacturers for finishing cast iron, also on steel parts such as are used on sewing machines, automobiles, bicycles, etc.

White polishing composition is used for the polishing of nickel or brass after plating, and in some cases solid metal which is not plated. This composition is used to good advantage on heavy nickel-plated work which is both cut and polished at the same time, after which a final polish or color is given with a composition such as Vienna lime. White composition can also be purchased for polishing and coloring all metals where a high color is required and for extra fine polishing of silver. Vienna lime is used in different grades, and it is necessary to know what class of

work is to be polished before any particular grade can be recommended. It is used for nickel polishing. Rouges are used for both coloring and polishing, and are made in red and black colors, the former more generally for steel and the latter for horn, rubber, celluloid, and sometimes metals.

**Preparation and Use of Abrasive Polishing Belts.** It will be well to present a few supplementary suggestions concerning the preparation and use of abrasive polishing belts. In every case, the abrasive must be fine enough for each operation, so that it does not produce scratches on the work; otherwise, time will be lost in removing these scratches before any really effective polishing can be done. The coarsest abrasive recommended in Table 2 is No. 70 which is for use on cast iron or steel. For very rough work, however, it may be found more desirable to take the preliminary cut with a belt carrying No. 46, after which an intermediate cut will be taken with a belt carrying No. 90, followed by a finishing cut taken with a No. 180 belt. Where a very fine finish is required, the work will be given a fourth operation, and the belt used for this purpose will be No. 220 greased. It is common practice to rub down used belts with an old file or stone and then grease them for the final polishing operation. In this way, the effective use of the belts is greatly increased. After all of these pieces have had the third operation performed on them, the abrasive on the No. 180 belt will be rubbed down and the belt will be greased ready for the final polishing. It will, of course, be understood that the recommendations made in Table 2 are only a statement of average practice. On some classes of work, such as polishing flat-irons, very satisfactory results have been obtained through taking the preliminary cut with a belt charged with No. 90 alundum, and then finishing the work with a No. 220 greased belt. One well-known firm obtains good results by polishing the work with a belt charged with either No. 70 or 100 alundum, and then using the same belts for a finishing operation, after they have become too badly worn for use in taking the preliminary cut. The abrasive is rubbed down with a file stub or piece of stone, and the belt is greased to adapt it for performing

the final polishing operation. On all classes of polishing operations, regardless of whether they are performed on abrasive belt machines or polishing stands, the selection of abrasives and methods of procedure must be based on judgment acquired through the actual performance of polishing operations under the conditions that exist in the shop where the work is to be done.